International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 9, Issue 5, Oct 2019, 973–984

EFFECT OF EGR ON PERFORMANCE OF CI ENGINE WITH DIESEL AND COTTON SEED OIL AS FUELS

KNV SREEDEVI[1], Dr. MVS MURALI KRISHNA[2], SUNAYANA[3] & BHOOMIKA[4]

[1]*Assistant Professor, Chaitanya Bharati Institute of Technology, Hyderabad, Telangana, India*

[2]*HOD, Department of Mechanical Engineering, Chaitanya Bharati Institute of Technology, Hyderabad, Telangana, India*

[3,4]*Student, Chaitanya Bharati Institute of Technology, Hyderabad, Telangana, India*

ABSTRACT

Automobile emission is one of the major problems in the environment. Engine emits the carbon monoxide (CO), unburnt hydrocarbon (HC) and smoke density, etc and causing a variety of health and environmental problems at the locations far from their emissions source. These problems include ground level ozone and smog, which are created in the atmosphere. Motor vehicle emissions contributes to air pollution and are a major source in the creation of smog in some large cities. The health risks of air pollution are extremely serious.

In general, an exhaust gas is a gas emitted through a combustion process. The exhaust gas is actually a combination of many different gases; N_2, CO_2, H_2O and O_2. One of the most dangerous is CO, carbon monoxide. This gas has the potential to kill people and animals if concentrations are high enough. Hydrocarbons come from unburned fuel. NO_x are released through the combustion process and have been linked to acid rain and ozone.

One of the ways to reduce the emission from the exhaust gas is Exhaust Gas Re-Circulation (EGR), where certain amount of exhaust gas released out from the exhaust manifold is cooled and directed into the inlet manifold. Complete combustion of fuel leads to minimum emissions. A double pipe, counter flow heat exchanger was designed for this purpose.

The present work deals with the effect of EGR on performance characteristics like specific fuel consumption, brake thermal efficiency and exhaust gas temperature.

The high consumption of diesel fuel not only in agriculture section but also in transport sector compels for the substitution of diesel fuel with suitable alternate fuel. Hence, performance characteristics with diesel and cotton seed oil as fuel in a conventional, unmodified diesel engine with and without EGR are compared in the work.

Experiments were conducted on vertical, 4 stroke, single cylinder (with electric generator) diesel engine with various EGR percentages and without EGR. It was observed that, at 15% EGR with diesel as fuel, engine performance improved and there is very minute effect of varying EGR percentage of cotton seed oil though the performance is relatively good.

KEYWORDS: EGR, Exhaust Manifold, Heat Exchanger, Specific Fuel Consumption, Brake Thermal Efficiency & Exhaust Gas Temperature

Received: Jul 30, 2019; **Accepted:** Aug 19, 2019; **Published:** Sep 25, 2019; **Paper Id.:** IJMPERDOCT201986

Symbol	**Name**
Q	Rate of heat transfer
m	Mass flow rate
c_p	Specific heat at constant pressure
T	temperature

Original Article

U	Over all heat transfer coefficient
LMTD	Log mean temperature difference
Pr	Prandtl number
μ	Dynamic viscosity
k	Thermal conductivity
Re	Reynolds number
ρ	density
v	velocity
Nu	Nusselt number
h	Convective heat transfer coefficient

INTRODUCTION

Exhaust gas recirculation (EGR) is a nitrogen oxide (NO_x) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. This dilutes the O_2 in the incoming air stream and provides gases inert to combustion to act as absorbents of combustion heat to reduce peak in-cylinder temperatures. NO_x is produced in high temperature mixtures of atmospheric nitrogen and oxygen that occur in the combustion cylinder, and this usually occurs at cylinder peak pressure.

The present work lays emphasis on the effect of various proportions of EGR on performance of conventional diesel engine. The effect of EGR on the performance of the engine with cotton seed oil as fuel has also been investigated.

MOHD HAFIZIL MAT YASIN et al., [1] experimented with mineral diesel and palm biodiesel operated with two different modes (EGR and normal) in a diesel engine at full load at 2500 rpm. Increase in fuel economy is obtained with the use of palm biodiesel and EGR employment at the specific engine speed. The decreases in the exhaust gas temperature were obtained when the EGR was employed for both test fuels. NOx emission was reduced significantly when the EGR was applied with increases in CO and UHC emissions were obtained for both test fuels.

S. PAI et al., [2] found that the engine can be run without any abnormality when modified to implement EGR in it. Because of the fact that EGR admits the inert gases in the chamber which have specific heat higher than that of air, so, they absorb the heat of combustion and also dilute the fresh air which increases the ignition delay and hence, reduce the heat of combustion which ultimately result in lower exhaust gas temperature and lower NOx emission. Exhaust gas recirculation (EGR) has been found a very effective way to reduce NOx emission from the diesel engine.

RAVINDRA SADASHIV DEASHPANDE et al., [3] investigated the performance and emission characteristics of diesel fuel with exhaust gas recirculation. The value of fuel consumption of the diesel engine with EGR is increased than that of without EGR system at same brake power. The Brake Thermal Efficiency (BTE) of the engine was partially lower and the Brake Specific Fuel Consumption (BSFC) of the engine was partially higher when EGR system was implemented with the engine. The engine performance on EGR system, exhaust gas temperature reduces as compared to that of without EGR system, so it is beneficial for surrounding. Compared with conventional diesel fuel, the exhaust NOx was reduced about 25% at 15% EGR due to less oxygen available in the recirculated exhaust gases which lowers the flame temperature in the combustion chamber. Emission of oxide of nitrogen (NOx) was very much reduced by the implementation of EGR system. The total unburnt HC and CO emissions were decreased by 5 and 10% for diesel fuel with EGR and smoke emissions were observed as increases, due to incomplete combustion. Emission of hydrocarbon (HC) increases by implementing EGR system with engine than that of operating engine without EGR system.

SHUBHAM SURESH LAD et al., [4] found biodiesel as an oxygenated fuel that undergoes improved combustion in the engine due to the presence of molecular oxygen but leads to higher NO_x emissions. In the experiment, a higher NO_x emission was effectively controlled by 10% exhaust gas recirculation. Recycled exhaust gas lowers the oxygen concentration in the combustion chamber and increases the specific heat of intake charge which results in lower flame temperature and reduction in NO_x formation. Brake thermal efficiency of biodiesel was found to be comparable with diesel at full load. The experimental analysis on a single cylinder diesel engine with diesel and biodiesel blend at 10% EGR has proved minimized pollution and improved performance. There was an average reduction of 40% NO_x emission was obtained by 10% EGR. When the engine utilizes biodiesel, tt concludes that the Brake Thermal Efficiency of engine reduces with increase in EGR percentage. They found that at 10% EGR the specific fuel consumption increases considerably. As many research says that NO increases rapidly by using bio-diesel. Applying EGR was an impressive technique to reduce the NO emission.

MESHACK HAWI et al., [5] modified a single cylinder, four stroke diesel engine into a dual-fuel engine that used diesel as pilot fuel and biogas as the primary fuel. An experimental study was then conducted on the engine to investigate the various effects of EGR on the performance and emission characteristics of a dual-fuel single cylinder four stroke DI diesel engine under various experimental conditions. The following conclusions were drawn from the analysis:

- It was found that with increase in the percent of EGR, the brake thermal efficiency increased and specific fuel consumption decreased. It was observed that with rise in percentage of EGR the percentage increase in brake thermal efficiency was up to 10.3% at quarter load and up to 14.5% at full load for single fuel operation while for dual-fuel operation an increase up to 9.5% at quarter load and up to 11.2% at full load was observed. From experimental results it was found that an EGR percentage of around 20% resulted in maximum BTE and minimum BSFC. Brake thermal efficiency, increased at low EGR ratios due to the recirculation of active radicals from EGR that made the combustion process to be enhanced, so will result in an improvement in brake thermal efficiency.
- Results also showed that the brake power was not affected significantly by EGR.
- Experiments were carried out using the setup to prove the efficacy of EGR as a technique for NO_X reduction. It was seen that the exhaust gas temperatures reduced drastically by employing EGR. This indirectly showed the potential for reduction of NO_X emission. This can be concluded from the fact that the most important reason for the formation of NO_X in the combustion chamber is the high temperature of about 2000 K at the site of combustion. It was found that EGR reduced the exhaust gas temperature by up to 7.6% at minimum engine loading and up to 2.3% at maximum loading.
- EGR caused a slight increase in carbon monoxide (CO) and hydrocarbon (HC) emissions. Increasing EGR reduced the amount of oxygen and led to incomplete combustion and therefore increased CO and HC emission due to lower combustion temperature.

KNV SREEDEVI et al., [6] experimented on four stroke single cylinder diesel engine with EGR, magnetic field and combination of both with diesel as fuel and found that the engine with the combination of magnetic field and EGR at 5% and 10% showed best performance characteristics.

MATERIALS AND METHODOLOGY

Experiments were conducted on a modified multi-cylinder water cooled diesel; engine with 3.68 kW at 1500 rpm. The schematic diagram of experimental setup is shown as in Figure 1. The engine specifications are given in Table 1. Thermocouple in conjunction with a digital temperature indicator was used for measuring exhaust gas temperature. For the measurement of water flow rate for engine cooling exhaust gas calorimeter, rotameter were provided. The specifications of the diesel engine are tabulated in Table 1 and a schematic representation of complete set up is show in Figure 1

Table 1: Specification of Engine

Make/Model	Kirloskar
Engine	4-s, single cylinder with electric generator
Power	3.68KW@1500 rpm
Bore	80mm
Compression ratio	16:1
Stroke length	110mm

HEAT EXCHANGER DESIGN

A double pipe heat exchanger was designed for cooling the exhaust gas from the exhaust modified in the engine. To control the exhaust gas flow rate into the heat exchanger a valve was provided in between the engine exhaust and heat exchanger which has a valve for controlling the flow rate in initial stages. The heat exchanger was designed with following input data: mass flow of exhaust gas, mass flow of air, inlet temperature of hot fluid (i.e., exhaust gas), inlet temperature of cold fluid (i.e., air at room temperature), diameter of tube, specific heat of exhaust gas and air. Using standard heat transfer equation, the heat transfer coefficient was calculated.

Design Parameters

$$Q = mcpdT = U.A.LMTD$$

Prandtl Number

$$Pr = \frac{c_p \mu}{k}$$

Reynolds Number

$$Re = \frac{\rho v D}{\mu}$$

From dittus boelter's equation:

Nusselt Number

$$Nu = 0.023 \times Re^{0.8} \times Pr^{0.4}$$

Convective heat transfer coefficient;

$$h = \frac{Nu\, K}{D}$$

$$U = \frac{1}{\frac{1}{h_i} + \frac{1}{h_o}}$$

$$A = 2\pi d_i L$$

d_i = 25.4 mm (diameter of inner pipe)

Finally, the required heat transfer surface area and length of the pipe is used for multi-pass (i.e., 2-pass) was determined. The dimensions of inner and outer tube with length are tabulated in Table 2.

Table 2: Specifications of the Heat Exchangers

Type	Counter flow,Double pipe
Inner tube diameter	25.4 mm
Outer tube diameter	50.8 mm
Length of heat exchanger	150 cm(it's determined later)
Number of passes	2

The heat exchanger is a device used to transfer heat from body of higher temperature to the lower temperature, here exhaust gas is a high temperature gas and ambient air is a low temperature gas. Here, heat is exchanged in counter flow direction as the heat transfer is high.

Figure 1: A Two Pass Double Pipe Heat Exchanger.

The inner pipe of heat exchanger is made of copper and outer of steel. Air is made to flow in the annular space and exhaust gas in inner pipe. Exhaust gases coming out of the combustion chamber after the exhaustion through the exhaust manifold cannot be directly sent to mix with oxygen for the intake because this exhaust gases are at high temperatures and contain smoke, particulate, smog, which must be cleaned so certain amount of exhaust gases made enter into heat exchanger as and then into filter for the removal of particulates and smog. Complete removal of smog is not yet discovered. Then, this filtered gas is sent into control valve, control valve is the heart of EGR because the control valve controls the amount of exhaust gas mixing with oxygen.

Figure 2: Photographic View of Experimental Setup.

Figure 2 illustrates the photographic view of the experimental setup. On conventional engine, the double pipe heat exchanger was mounted and the exhaust gas was re-circulated into combustion chamber of the engine.

The exhaust gas was cooled with air coming from the air compressor and pressure of air coming from the compressor is 2 kg/cm^2, since it is a counter flow heat exchanger, the exhaust gas flows through the inner tube and cooling air passes through annular space around the inner tube.

Now the experimental investigation was carried out with different percentages of exhaust gas such as 0%, 5%, 10%, 15%, 20% mixing with oxygen and with the each varying loads such as no load, 25% load, 50% load and full load conditions for both diesel and cotton seed oil. Table 3 illustrates the different properties of both diesel and cotton seed oil.

Table 3: Properties of Diesel and Cotton Seed Oil

Property	Diesel	Cotton Seed Oil
Calorific value	44,800kJ/kg	39,648 kJ/kg
Fire point	68^{o}C	322°C
Flash point	52-95^{o}C	316°C
viscosity	0.278 poise	2.52 poise
density	0.916 kg/m^3	0.832kg/m^3
Cetane number	50	41.8

The Brake Specific Fuel Consumption(BSFC), Brake Thermal Efficiency(BTE) and Exhaust Gas Temperature(EGT) are tabulated and compared graphically for both diesel and cotton seed oil with above varying percentages.

RESULTS AND DISCUSSIONS

The first experiment was carried out on a conventional diesel engine without exhaust gas re-circulation and various performance characters such as brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature were analyzed.

Table 4: Performance Characteristics of Engine without EGR

Characteristics	Load 100%	Load 50%	Load 25%
BSFC(Kg/KWhr)	0.2805	0.410	0.691
BTE	8.48	5.19	3.44
EGT(°C)	260	250	200

Table 4 represents the performance characteristic of conventional diesel engine without EGR. The decrease in fuel consumption, increase in exhaust gas temperature and increase in thermal efficiency was observed with the increasing load.

An experiment was carried out on a conventional diesel engine with exhaust gas recirculation using diesel as fuel and various performance characters such as brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature were analyzed.

Table 5: Variation of Brake Specific Fuel Consumption with Percentage of Load at Various Percentage of EGR

EGR	100% Load	50% Load	25% Load
0	0.2805kg/kwhr	0.410	0.691
5	0.2805	0.410	0.691
10	0.2805	0.410	0.678
15	0.271	0.400	0.678
20	0.302	0.391	0.651

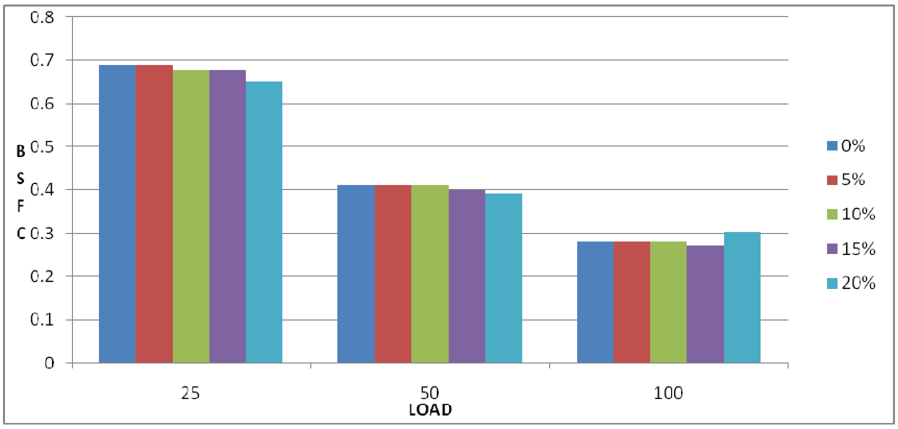

Figure 3: Shows the Histogram of variation of Brake Specific Fuel Consumption with Percentage of Load at various Percentage of EGR.

Figure 3 represents histograms showing variation of BSFC at the various percentage of loads at a different percentage of EGR. At 25% of load, with 5% EGR BSFC remains constant in compression with engine of no EGR. At the same load, with 10% EGR, BSFC decreased by 2% in comparison with engine with no EGR. At the same load, with 15% EGR, BSFC decreased by 2% in comparison with engine with no EGR. At the same load, with 20% EGR, BSFC decreased by 6% in comparison with engine with no EGR.

Similarly, at 100% of load, with 5% and 10% EGR, BSFC remains same in comparison with engine with no EGR. At the same load, with 15% EGR, BSFC decreased by 1% in comparison with engine with no EGR. At the same load, with 20% EGR, BSFC decreased by 4% in comparison with engine with no EGR.

Table 6: Shows the Variation of Brake Thermal Efficiency with Percentage of Load at various Percentage of EGR

EGR	100% Load	50% Load	25% Load
0	80.48%	50.79%	30.44%
5	80.48%	50.79%	30.44%
10	80.48%	50.79%	30.51%
15	80.75%	50.94%	30.51%
20	70.88%	60.08%	30.65%

Table 6 represents the brake thermal efficiency variation with the change in load

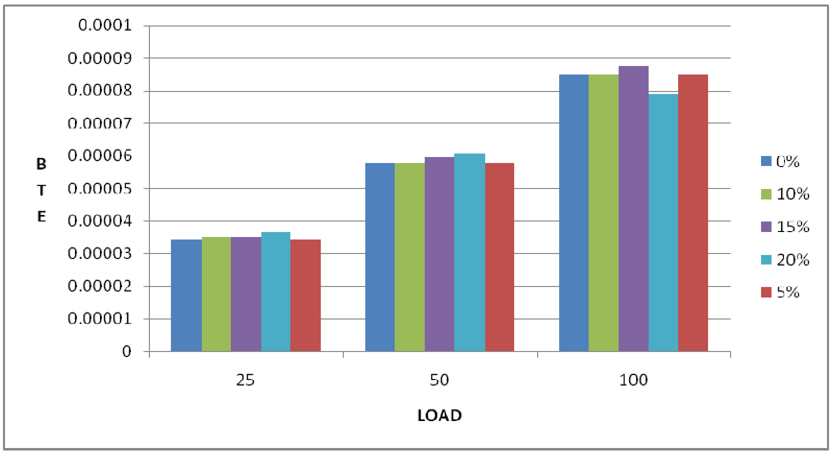

Figure 4: Shows the Histogram of Variation of Brake Thermal Efficiency with Percentage of Load at Various Percentage of EGR.

Figure 4 represents a histogram showing BTE at the various percentage of loads of different percentage of EGR. At 25% of load, with 5 and 10% EGR, BTE is increased by 1% in comparison with engine with no EGR. At the same load, with 15% EGR, BTE is increased by 3% in comparison with engine with no EGR. At the same load, with 20% EGR, BTE is remains constant in comparison with engine with no EGR. Hence it is observed that, as % of EGR is increased, BTE is increased, BTE decreases at different load at 25% load. This might be due to prevention of fresh air supply to the engine by the exhaust gas.

Similarly, at 100% of load, with 5and 10% EGR, BTE decreased by 0.5% in comparison with engine with no EGR. At the same load, with 15% EGR, BTE increased by 3% in comparison with engine with no EGR. At the same load, with 20% EGR, BTE decreased by 6% in comparison with engine with no EGR. Similar trends were observed with those of BTE curve at various loads with different % of EGR.

Table 7: Variation of Exhaust Gas Temperature in Celsius with Percentage of Load at various Percentage of EGR

EGR	100% Load	50% Load	100% Load
0	200^{o}C	250	260
5	200	240	280
10	200	25	300
15	200	250	330
20	190	250	330

Table 8 represents brake thermal efficiency variation with change in load.

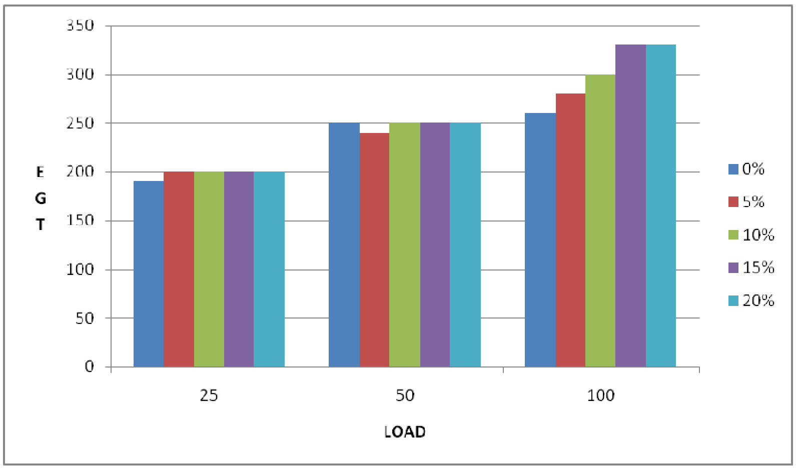

Figure 5: Represent Histograms Variation of Exhaust Gas Temperature with Percentage of Load at Various Percentage of EGR.

Figure 5 represents histogram showing variation of EGT at various percentage of loads at different percentage of EGR. At 25% of load, with 5, 10, 15 and 20% EGR, EGT increase by 3% in comparison with engine with no EGR.

Similarly, at 100% of load, with 5% EGR, EGT increase by 8% in comparison with engine with no EGR. At the same load, with 10% EGR, EGT increased by 16% in comparison with engine with no EGR. At the same load, with 15 and 20% EGR, EGT increase by 28% in comparison with engine with no EGR. Hence it is said that, at 0% EGR, BSFC was observed to be minimum at various loads.

An experiment was carried out on a conventional diesel engine with exhaust gas re-circulation using cotton seed oil as fuel and various performance characters such as brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature were analyzed.

Table 8: Shows the Variation of Exhaust Gas Temperature with Percentage of Load at Various Percentage of EGR

EGR	100% Load	50% Load	25% Load
0	350	260	145
5	30	280	190
10	370	295	205
15	370	295	225
20	375	300	225

Table 9 Shows variation of Exhaust Gas Temperature (EGT) at various with % of loads at different % of EGR.

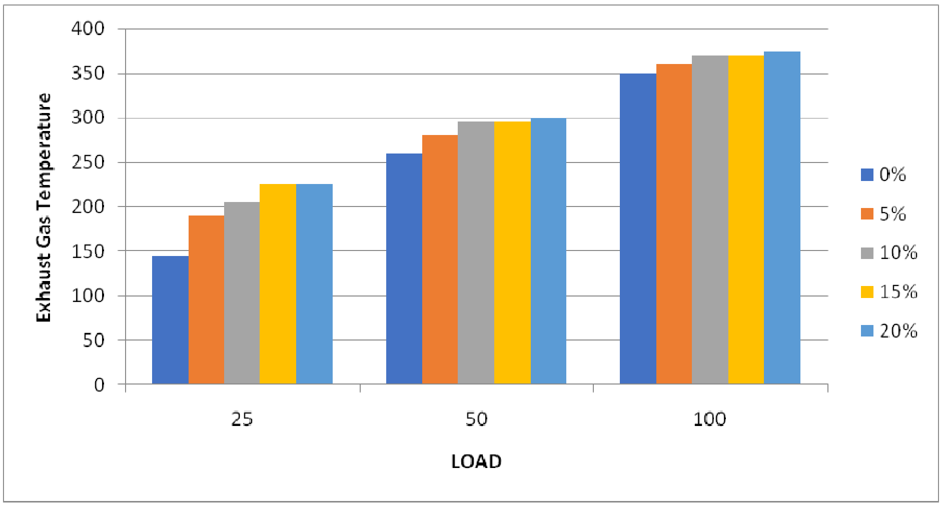

Figure 6: Represents Histogram Variation of Exhaust Gas Temperature with Percentage of Load at various Percentage of EGR.

Figure 6 represents histograms showing variation of EGT at the various percentage of load at a different percentage of EGR. At 25% of load, with 5% EGR, EGT increased by 30% in comparison with engine with no EGR. At the same load, with 10% EGR, EGT increased by 41% in comparison with engine with no EGR. At the same load, with 15% EGR, EGT increased by 53% in comparison with engine with no EGR.

Similarly, at 100% of load, with 5% of EGR, EGT increased by 2.5% in comparison with engine with no EGR. At same load, with 10 and 15% of EGR, EGT increased by 5% in comparison with engine with no EGR. At the same load, with 20% of EGR, EGT increase by 7% in comparison with engine with no EGR. hence it is said that, as load increase and percentage of EGR increases then EGT increased.

Table 9: Ahows the Variation of Brake Thermal Efficiency with Percentage of Load at various Percentage of EGR

EGR	100% Load	50% Load	25% Load
0	7.437×10^{-8}	5.105×10^{-8}	3.1673×10^{-8}
5	7.437×10^{-8}	5.105×10^{-8}	3.1673×10^{-8}
10	7.437×10^{-8}	5.105×10^{-8}	3.1673×10^{-8}
15	7.437×10^{-8}	5.105×10^{-8}	3.1673×10^{-8}
20	7.437×10^{-8}	5.105×10^{-8}	3.1673×10^{-8}

Table 10 shows variation of BTE with percentage of load variation percentage of EGR. As load increases, BTE increases.

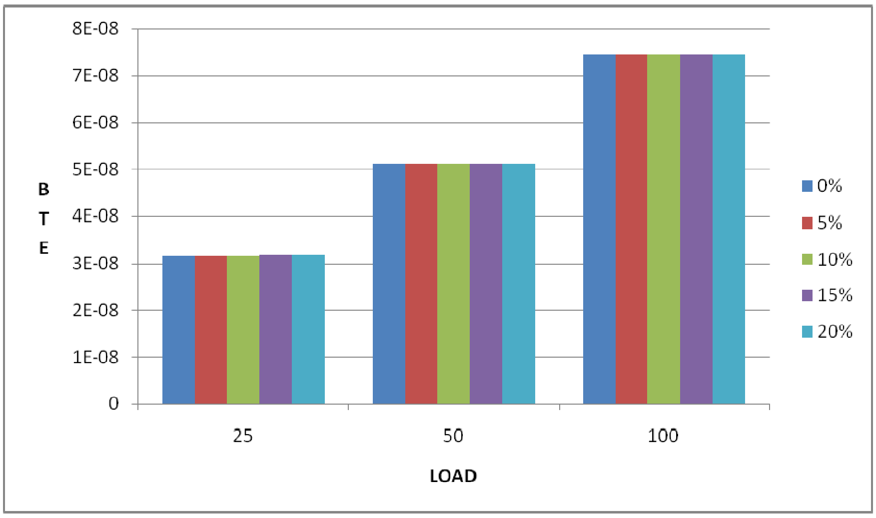

Figure 7: Represents a Histogram Variation of Brake Thermal Efficiency with Percentage of Load at Various Percentage of EGR.

Figure 7 represents a histogram showing BTE at a various percentage of loads at a different percentage of EGR at 25, 50 and 100% of load BTE remains constant as the percentage of EGR varies. As the load increases, BTE increases.

Table 10: Shows the variation of brake specific fuel consumption with percentage of load at various percentage of EGR

EGR	100% Load	50% Load	25% Load
0	0.342	0.498	0.803
5	0.342	0.498	0.803
1	0.342	0.498	0.803
15	0.342	0.498	0.803
20	0.342	0.498	0.803

Table11 shows a brake thermal fuel consumption (BSFC) with a percentage of loads at a different percentage of EGR. BSFC decreased with the load at a various percentage of EGR.

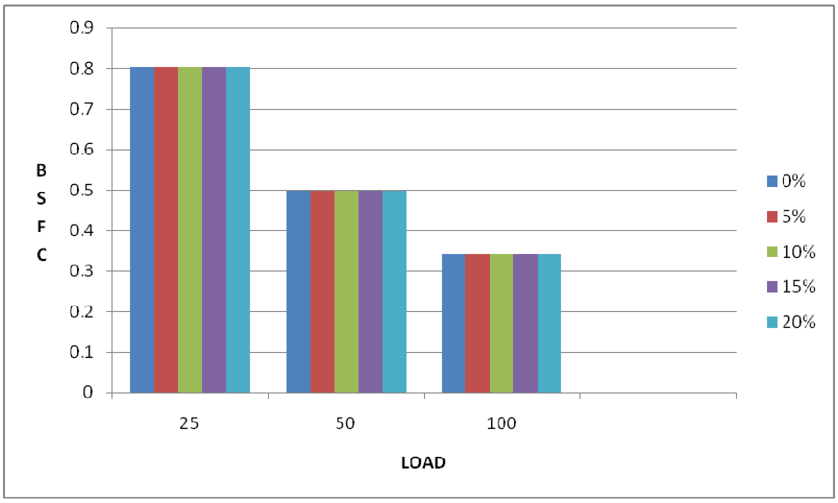

Figure 8: Represent Histogram Variation of Brake Specific Fuel Consumption with Percentage of Load at Various Percentage of EGR.

Figure 8 represents the histogram showing variation of BSFC at a various percentage of loads at a different percentage of EGR. At 25, 50 and 100% BSFC remains constant for different percentages of EGR. As a percentage of load increases, BSFC decreases.

CONCLUSIONS

- Comparative to the conventional diesel engine the performance characteristics such as brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature were found to be improved with EGR using diesel as fuel.
- At 15% of EGR and 100% load, using diesel as fuel, the performance of the engine greatly improved.
- With cotton seed oil as fuel, the performance characteristics are independent of percentage of EGR but with the increase in load, BSFC decreased, BTE increased and exhaust gas temperature increased.

FURTHER SCOPE

- Experimentations can be done by mixing certain percentage of cotton seed oil with diesel and the effect of same on performance and emissions of the engine with EGR can be studied. That is, the effect of EGR using blended fuels and emissions can also be analyzed.

REFERENCES

1. *Mohd hafizil mat yasin,"Study of a Diesel Engine Performance with Exhaust Gas Recirculation system with palm biodiesel."*
2. *S. pai,**"** The study of EGR effect on diesel engine performance and emission-a review."*
3. *Ravindra Sadashiv Deashpande,**"** Performance of diesel engine with EGR system."*
4. *Shubham suresh lad,**"**Experimental Investigation of EGR Effect on Emission Characteristics of a Diesel Engine, Fueled with Biodiesel."*
5. *Meshack hawi,"Effect of Exhaust Gas Recirculation on Performance and Emission Characteristics of a Diesel-Piloted Biogas Engine."*
6. *Hymavathi, D., Prabhakar, G., & Sarath, B. B. (2014). Biodiesel production from vegetable oils: an optimization process. Int J Chem Petrochem Technol, 4(2), 21–30.*
7. *KNV Sreedevi,"Experimental Investigation on Four Stroke Single Cylinder Diesel Engine with EGR and Magnetic field."*